YOU CAN BUILD THIS MODEM FOR YOUR COMMODORE 64

PART I

Sure you can build your own modem... And save a lot in the process!

JIM STEPHENS

■Modems are expensive but not all that complicated. In fact, they can be quite simple once the function of the main components is understood. Basic modems have two main sections, a modulator and a demodulator. Once these have been built, the rest is easy. Here's how to build your own originate-only modem and save a bundle.

What makes it possible, are two new integrated circuits sold by Radio Shack and other suppliers. The catalog description said that the XR2211 IC was an "FSK decoder used for RTTY and modems." Next to it was another IC, the XR2206 FSK Generator, which had the same caption. The result was better then expected, it worked, and it worked reliably. The circuit could do what it took several dozen IC's in other circuits to do and it did it at less than half the cost of some of the more popular modems for the Commododre 64.

A modem is a circuit that converts serial digital data coming from the computer into tones that can be sent over a single audio channel such as the telephone line. This conversion, called modulation, sends one tone for a digital one and a different tone for a digital zero. The other section of a modem converts tones from the telephone line to either a digital one or zero depending on the tone's frequency. This function is called demodulation.

Since the telephone is built to handle voice communication, the plus and minus voltages which are generated by the computer cannot be handled by the telephone circuits. If a circuit could recognize a certain voltage and convert that voltage to either high or low tone, digital generated tones could be sent over the telephone line and could be reliably picked up at the other end.

That is exactly what the modem does.

To speed things up a bit, modems actually operate using four tones of different frequency. Two tones are used by the sending terminal and two separate tones of another frequency range are used by the receiving terminal. This way, it is possible for both units to talk at the same time and not interfere with each other's data.

The telecommunications terminal that calls up another terminal is called the originating terminal. Its tones are set at 1070 Hz and 1270 Hz for a digital zero or a one. The receiving terminal is the answering unit

and its tones are higher with a one represented by 2225 Hz and a zero represented by 2025 Hz. When the two tones are changed from one frequency to the next, they are not stopped and started, but shifted up or down in frequency. This is called "frequency shift keying" or FSK. A demodulator circuit recognizes this shift and changes the digital output at its output pin accordingly. The modulator circuit senses a digital one or zero on its keying input pin from the computer and shifts its output frequency either up or down depending on the level of voltage at this input.

Although it is possible to have both the originating and answering capability in one modem, the need for more-complicated circuits outweigh the benefit. After all, most of us would only use our computer to call up another terminal such as Compuserve. We rarely use it to answer unless we are running our own bulletin board. The simple unit shown here is an originate-only modem, but it could easily be converted to answering capability by changing the values of the components as shown in Table I and setting the output tones of the modulator to the higher set of frequencies. It might even work if a separate set of components were on the board and switched into by a set of switches. This would make the modem capable of both origination and answering.

The most expensive part of telecommunicating can be the modem software that generates and converts the digital data once the modem has accomplished its task. The unit shown here works with most of the available software for Commodore modems. It was used with Smart Terminal 64, Victerm, and with Term 64. Many good terminal programs have been published recently in several of the Commodore publications.

The modem circuit

There are four ICs that make up this modem circuit, but the two major ones are the 2211 FSK demodulator and the 2206 FSK modulator.

As shown in Figure 1, the 2211 demodulator receives the 2225 Hz tone from the earpiece. The level of the received tone is amplified by IC3 which is an LM386 low power audio amp. The descrete components that connect to the 2211 actually set the response frequency of the demodulator. Table I shows the values of the components that set the frequencies at which the demodulator responds. Since we want the demodulator to react to the incoming 2025 Hz and 2225 Hz tones, we have chosen the values for the five components listed under the higher frequency range. Note that the capacitors here should be good quality mylar types to improve the stability of the circuit. Pins 11 and 12 of the 2211 are the oscillator control of the demodulator and this oscillator is peaked by a 5K variable resistor, R7. This is a standard linear taper pot. The tones are transmitted from the earpiece by a small inexpensive speaker.

When a tone in the proper frequency range is detected by the 2211, the demodulator's data output pin goes either high or low depending on the frequency. A tone of 2225 Hz will cause it to go high while a tone of 2025 Hz will cause it to go low. Adjustment of R7 causes the oscillator to lock onto this frequency range and these adjustments will be discussed in detail later.

The heart of the modulator section is the 2206 FSK generator. Figure 1 shows that it appears as simple as the demodulator but its adjustment is much more complicated than the 2211. It generates a tone of either 1070 Hz or 1270 Hz at pin 2 when either a digital zero or a digital one is detected at its keying pin number 9. The 2206 is capable of producing most any frequency so exact adjustment is necessary in order to produce the correct frequency output.

Pins 7 and 8 of the 2206 connect to the timing resistors that produce the two output frequencies. The value of these resistors is set to produce the two separate tones. Two variable resistors (R13 and R14) have been chosen so that the exact frequency of the tones can be set by hand. R11 is the volume control that determines the intensity of the tone being sent to

PARTS LIST

Resistors
All resistors ⅛-watt
R1, 4—1,000,000 ohms
R2, 10, 12—5100 ohms
R3—510,000 ohms
R5—200,000 ohms (see table 1)
R6—18,000 ohms (see table 1)
R7—5000 ohms Variable
R8, 13, 14, 16—10,000 ohms Variable
R9—10 ohms
R11—25,000 ohms Variable
R15—200 ohms

Capacitors
C1, 4, 7, 10—.1μF ceramic
C2, 8, 11, 14—10 uF electrolytic
C3, 15—5 μF electrolytic
C5—.005 μF ceramic
C6—.05 μF ceramic
C7—.1 μF ceramic
C9, 12—1 μF electrolytic
C13—100 μF electrolytic
C16—.022 μF mylar (see table 1)
C17—.0047 μF mylar (see table 1)

Semiconductors
IC1—XR2211 FSK Decoder
IC2—XR2206 FSK Generator
IC3, 4—LM386 Low Power Audio Amp
IC5—4049 CMOS Hex Inverter
Q1—2N2222 NPN Transistor

Miscellaneous
SW1—SPST Switch
SPKR—8 ohm .5 watt Speaker
Connecto-Edge Connector (Cinch #50 24A-30)
Perfboard
(1) 14 pin WW Socket
(3) 16 pin WW Socket
NOTE: - A ten-minute cassette tape containing five minutes of continuous telecommunications data and examples of both originating and answering tones may be ordered by sending $4.00 to Syntronics, 2324 Dennywood Dr., Nashville, TN 37214.

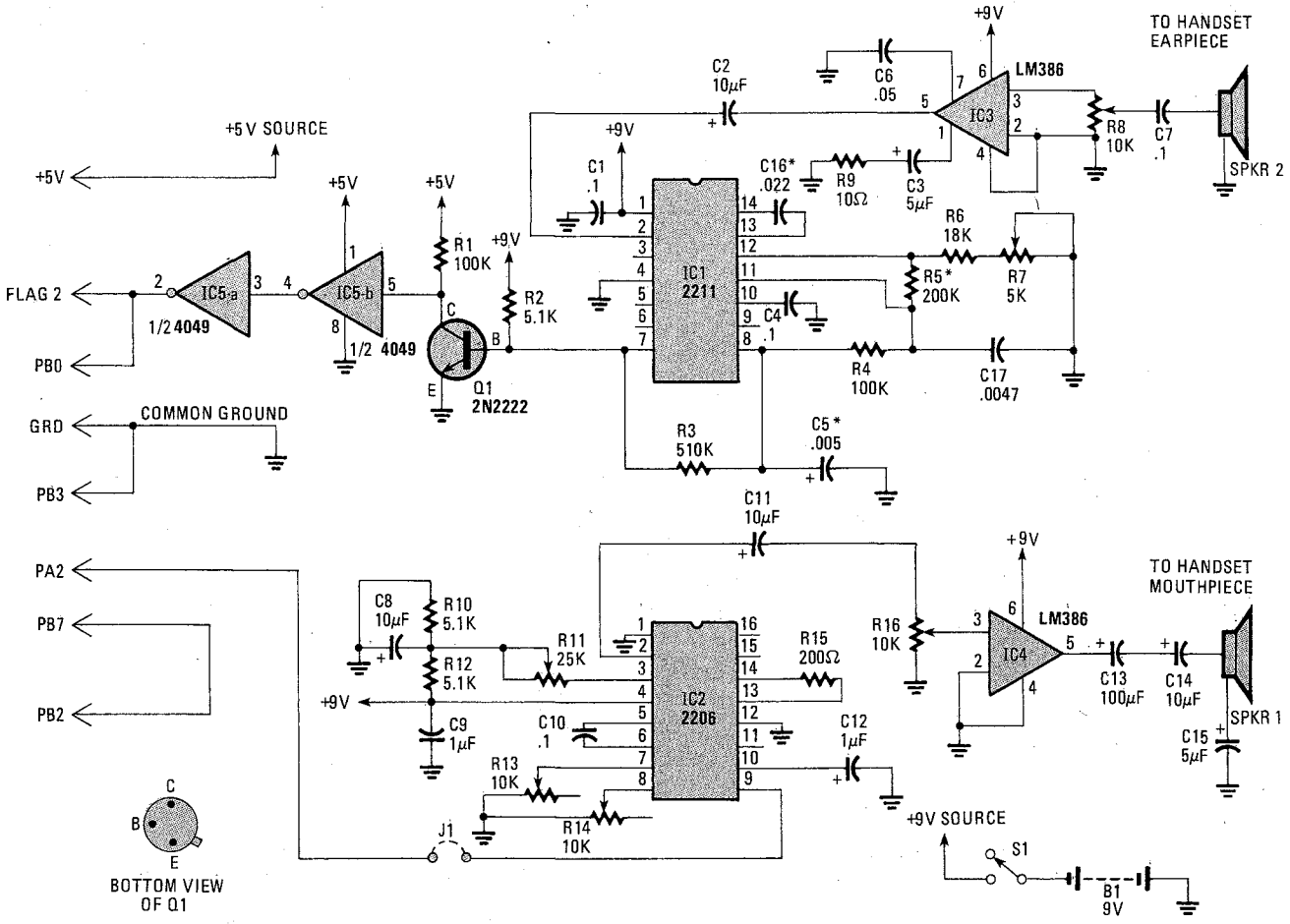

FIG. 1—SCHEMATIC DIAGRAM OF THE MODEM. Heart of the system is two IC's, IC1 and IC2 which are an FSK Decoder and an FSK Generator. Balance of circuit is straightforward and supports these devices. *See Table 1 for values.

IC4 which is an LM386 low power audio amp. The audio amp also has a 10K pot that adjusts the level of the final output to the 8 ohm speaker.

Circuit power

Notice that both the 2211 and the 2206 are powered by 9 volts. This voltage is necessary because the 2206 will not operate at less than 8.5 volts. Since direct current at 9 volts is not present on the user port of the Commodore 64, we use a 9 volt transistor battery. A small separate power supply could be built to provide this voltage. The modem only draws around 25 ma so the battery should last some time depending on use.

A transistor battery should never be placed on the user port pins. If this were done, the output port of the 64 could be harmed. The output signal of the 2211 demodulator is connected to the 64 through a 2N2222 NPN transistor which obtains its power from the 5 volts on the user port. The signal is then fed through two stages of IC3 which is a CMOS 4049 inverter. The inverter is powered by the computer's 5 volts. This IC shapes the final digital levels before they are presented to the port. Both power supplies have their ground connection in common for proper signal reference.

After extended use, it will be necessary to replace the 9-volt battery since the lower voltage level will cause the modem's output and lock-on frequency to drift off. This will cause mis-reads in the data. If garbage starts showing up for no reason, suspect low battery voltage. Again, this would not be a problem if a small separate 9-volt supply were constructed, though it would increase the complexity and cost of the circuit. The transistor battery did fluctuate when left off for a long period and would sometimes make re-tuning necessary.

Wiring the modem board

You must keep the components close together and the leads short or risk stray capacitance which upsets the audio circuits. This is especially true of the LM386 amplifiers. You may hear a local disk jockey coming in on the modulator circuit. This interference disappears once the final connections are made. Make sure you use flexible sheilded microphone cable to the speakers. These lines should be no more than ten inches long. They tend to act as antennas and the modem will try to decode the sound of the latest rock group.

IC sockets were used for the integrated circuits and wire-wrap posts for mounting some of the descrete components. One 16 pin IC socket mounted both of the LM386 amplifiers. The sockets were inserted into a 3-inch by 2-inch perf board. Leave the jumper test point (J1) disconnected until the final adjustments have

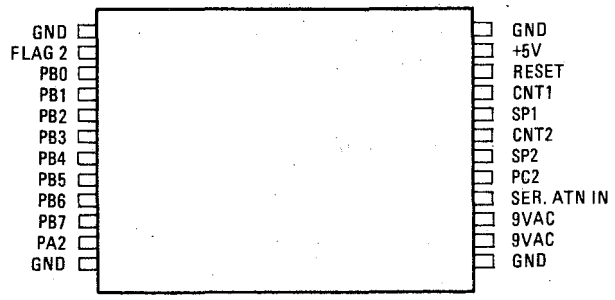

FIG. 2—DIAGRAM OF THE COMMODORE 64 user port. Make sure that the connector is properly oriented before attaching to user port.

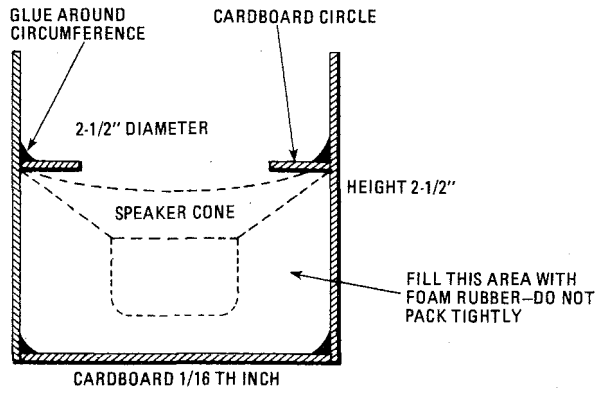

FIG. 3—CONSTRUCTION OF ACOUSTIC COUPLER. Speakers are backed with foam to keep sound in and interfering noise out. Extraneous noises can turn data to garbage.

been completed.

The parts list shows the values for the various components and many of these can be just within the value range shown. Those that are marked with an asterisk and shown by Table I must be the exact values listed. Those components connected to the LM386 amps should also be exact. You may want to diagram or label the variable resistors on the board layout since they can get confusing once final adjustments are started.

Connection to the computer is critical. It is important that the correct user port pins are selected for connection. Connections to the board is through very short lengths of hook-up wire. Some of the pins on the user port such as PBO and FLAG 2 are wired in parallel. This is necessary because of the way some software handles the output and input ports. Figure 2 shows the user port pinout which is viewed as though you were looking at the user port from the back of the computer. The connector to the port must always be inserted with the leads correctly oriented to the port pins. Never insert the connector upside down since this would place the unregulated alternating 9 volts of the port on the data lines. This could harm the port also. Some anti-reversing means such as connector keying might be necessary on the connector to prevent accidental backward insertion. I simply marked one side of the connector as "TOP."

The 9-volt power supply is switched on and off by a SPST toggle switch. The 5-volts for IC5 and Q1 are supplied by the computer and it is activated when the 64 is turned on. With this dual power arrangement, it is easy to forget to turn off the modem when it is not in use. This tends to shorten the battery life somewhat. The low continuous tone of the modulator alerts you that the unit is operating.

The coupler is the housing for the mike and speaker and into which you insert the handset. It does not have to be elaborate. Use two lengths of heavy cardboard wrapped in a circle which fits the handset snugly. This cardboard circle is then taped around the circumference. The speaker and mike are placed into them and glued. Foam rubber is used to seal the back. The sealing is necessary since the tones are continuous and tend to be irritating after a while. In order to prevent damage to the speakers, a stiff cardboard circle was cut and glued over the speakers to keep the handset from touching them. The leads to the couplers should be short and the couplers can be permanently mounted on a board. Again, use flexible sheilded mike cable here. Figure 3 shows how the couplers are constructed. See Figure 4 to examine the author's unit.

TABLE 1

FSK BAND	COMPONENT VALUES
300 Baud frequency 1070–1270Hz	C16–.039μF C5–.005μF C17–.01μF R6–18K R5–100K
300 Baud frequency 2025Hz–2225Hz	C16–.022μF C5–.005 μF C17–.0047μF R6–18K R5–200K

TABLE 1—TABLE OF COMPONENT VALUES for the 2211 decoder. If decoder is built to be an answering device, values in the first part of the table should be used.

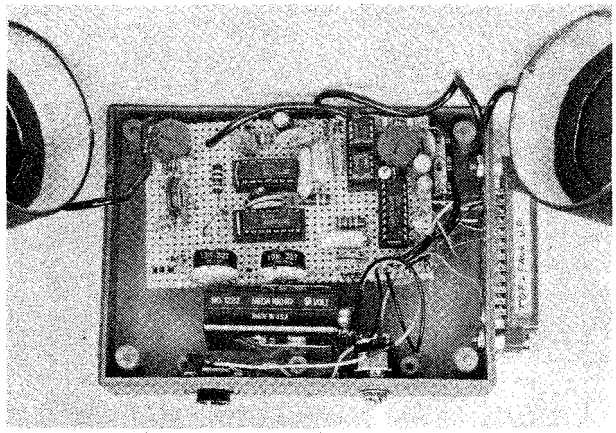

FIG. 4—AUTHOR'S UNIT with cover removed reveals simplicity of wiring. Component placement is not critical and perfboard works well.

That's all the room we have in this issue. However, we'll complete the Modem in the December Issue of **Computer Digest**. There's still much information to come!

YOU CAN BUILD THIS MODEM FOR YOUR COMMODORE 64

PART II

JIM STEPHENS

Last month we began a two-part article on how to build this Modem for your Commodore 64. Here is the conclusion of that article.

Circuit adjustment

The most difficult part of the whole project is the adjustment of the circuit for proper operation.

The Commodore 64 can be made to handle many of the chores done by expensive testers and generators. The 64 has a sophisticated sound chip. which we use to set the frequency of our modulator and can use the small program in Listing 1 to check the output of the demodulator. It is not the best alignment method, but it works.

Do not connect the modem to the user port yet. Turn the variable resistors R13 and R14 to the center of their adjustment. These are the timing resistors of the modulator that set the pitch of the two modulator tones. Flip the toggle switch on the modem to ON and you should hear a high-pitched tone coming from the speaker. If not, adjust R11 of the modulator upward and readjust R16 until the volume increases. Keep the volume low or the tone will become distorted. If no amount of adjustment produces a tone, there is probably a wiring error and the circuit needs to be rechecked. Always check the power leads first with a volt meter.

If a tone is being produced, connect test jumper 1 from pin 9 of the 2206 to ground with a small jumper. Notice that the tone changes. Each time ground is touched, the tone shifts frequency. This is the keying input of the modulator and it is this pin that reads the ones and zeroes from the computer. Turn the modem off and connect the modem to the user port. Remember to orient the connector properly. Turn on the 64 and the READY prompt should appear. If it does not, turn the 64 off check all connections on the connector and the wiring of the modem. Always check the voltage levels and their connections first. If the prompt appears, enter the frequency set program shown in Listing 1 and save it. Note that the modem is still off.

LISTING 1

```
 1 REM TEST TONE FOR 2225 HZ
 2 REM F=1070 HZ DATA = 69,114,150
 3 REM F=1270 DATA = 81,94,150
 4 REM F=2025 DATA = 130,67,150
 5 S=54272
10 FOR L=STOS+24:POKEL,0:NEXT
20 POKES+5,9:POKES+6,250
30 POKES+24,15
40 READHF,LF,DR
50 IF HF<0 THEN END
60 POKE S+1,HF: POKES,LF
70 POKE S+4,33
74 END
110 DATA 143,115,150
```

LISTING 1—TONE SETTING PROGRAM for the modulator. Data in line 110 is set to the numbers shown in lines 2 through 4 for the other frequencies as necessary. Data for a 2225 Hz tone is already shown in line 110.

The frequency set program is used to set the tones of the modulator. The small program is initially set up to produce a tone of 2225 Hz using the 64 sound chip. Line 2 through 4 of the program are REM statements that show the data statement changes necessary for the program to produce the other frequencies. Normally, the tones of the modulator will be set to 1070 Hz and 1270 Hz, but first, we must get the demodulator section working before these frequencies are finally set. The demodulator needs to be adjusted to respond to frequencies 2025 Hz and 2225 Hz. To do this, we need to set these frequencies into the modulator first since we will use the modulator section to feed the demodulator when we adjust it.

Run the frequency set program and a tone at 2225 Hz will sound through the TV/monitor speaker. Make sure jumper J1 is not connected to ground and turn on the modem. The tones from the two sources will be quite different. With each tone at about the same volume, adjust R13 (the one that connects to pin 7 of the 2066) until the tones are exactly the same. Listen to the pitch of each at the same time. As the tone of the modulator nears the same frequency of the TV/monitor, the sound will start to rapidly "chirp." This means that the tones are about the same frequency but not exact. Slightly turn variable resistor R13 until the chirps start to slow down to a slow "beat" like a wave of increasing and decreasing volume. The slower the wave, the closer the two tones are. If you have ever tuned a guitar using the fifth fret and listened to the beats, this will be no problem. If you find that all you can get is chirps,

you may be tuning to a harmonic of the 2225 Hz frequency and the tone on the modulator should be raised or lowered. If no amount of adjustment brings the slow beat, you might be tone deaf and should get a friend to help or your variable resistor is too critical and may have to be changed to another with a more even or smoother taper. If you have one, a 10-turn potentiometer works well here. Of course there might be a wiring error. Get the beat as slow as possible and proceed to the next step.

Connect the jumper (J1) to ground. Notice that the tone changed. Turn off the modem with SW1 and the tone on the TV/montor by entering RUN and hitting RUN/STOP quickly. Change the data in line 110 to that shown in line 4 of the program. This is the data that will produce our 2025 Hz tone. Repeat the above procedure while adjusting R14 (the variable resistor that connects to pin 8). Once the slow beat is obtained, you have the modulator tuned as though it were an answering modem. Alternately connect and disconnect J1 from ground and listen to the tone alternate from 2225 to 2025 Hz. We can now use these tones to set the demodulator section.

Tuning the demodulator

Place the modulator speaker near the mike of the demodulator. With the modem on, disconnect J1 from ground. The modulator should be producing a low volume 2225 Hz tone. Place a voltmeter or logic probe on the collector of Q1. The logic level should be high or around five volts. R8 (the volume control on IC3) should be about in the center of rotation. Connect J1 to ground and the output at the collector of Q1 should drop to zero volts. If it does not, vary R7 slowly on the demodulator until it does drop from high to low when ground is touched by the J1 lead. If no amount of adjustment produces this change, readjust the volume control R8 either higher or lower until the modulator locks in with the above adjustment. Once it does, alternately connecting and disconnecting ground with J1 will produce a high and low reading at Q1's collector. A partial low or high on the collector of Q1 is not correct. It must swing all the way to ground and most all the way to five volts. Keep adjusting R8 and R7 until you get the proper swing in voltage level. Don't readjust the timing resistors on the modulator, however, unless you feel the first frequencies could be wrong and you want to start over. Too much volume on the speaker and it could distort the tone being heard by the demodulator. It should work even with the modulator volume quite low. If the level does not change correctly adjust R8 on the LM386 of the demodulator for more drive. If you have one of the modem programs mentioned earlier, you can run it and type into the computer and the response of the modem should print out your typing correctly on the screen. This is yet another method to test the response of the demodulator.

Once the demodulator is responding correctly to the 2225 Hz and 2025 Hz tones, you can reset the modulator (the speaker) to the correct frequencies at which it will operate (1070 Hz and 1270 Hz). This is done with the same procedure as you used in the above example except you change the data in the frequency set program to read as shown in line 2 and 3 of the program. Remember that these tones must be almost exact to work correctly. You could be off as much as twenty cycles and the modem would still work with most answering terminals.

LISTING 2

```
10 OPEN 5,2,3,CHR$(6)
20 GET#5,A$
30 PRINT A$;
40 GOTO 20
```

LISTING 2—SMALL PROGRAM which reads the user port and prints resulting data characters on the screen. There are no ASCII interpretation tables so many of the characters will appear as graphics.

Testing the modem

With the speaker still placed near the mike, enter the small test program shown in Listing 2. Save it and enter RUN. The screen should clear. Then, by rapidly connecting and disconnecting J1 to ground, several graphic and alpha characters should appear on the screen in response to the varying tones. If you have a small modem program, you could call up a friend with an answering modem, insert the phone into the coupler's cups, and have the answering modem type some communications which could be used to check the unit. You can even use the small program in listing 2 but a lot of the data will appear as graphics although some of it can be read with a letter missing here and there.

If you are receiving data over the phone line, it may be necessary to slightly adjust the volume controls and even R7 on the demodulator for the best response. Do not readjust the timing resistors on the modulator however unless you are doing it using the frequency set program as in the above example. The mike's LM386 is not too powerful and the tone on the phone can get quite low. The LM386 amp is at its maximum gain/quality level and a bad connection and low answering volume may not make it through.

If you find that the answering modem is responding correctly to your modulator when you enter data, but the demodulator is not responding to the tone coming in, you probably have too much or too little volume going from the phone to the 2211. Try readjusting the volume control on the mike's LM386 until the data is correctly printed on the screen. Occasional garbage on the screen usually means low volume to the 2211 from the mike's LM386.

If all else fails, an audio tape is available from Syntronics that has all of the tones recorded and a continuous data stream in the answering frequency which can be used to adjust and set your new modem with the use of an audio tape recorder. Details of how to order are given in the parts list.

Above all remember, if it fails to work the first time, you can learn a lot from finding the fault. The feeling of accomplishment you get when it does work correctly is worth more than all the expensive modems ever produced.◀●▶